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(71) Applicants *(for all designated States except US)*: **AB VOLVO** [SE/SE]; S-405 08 Göteborg (SE). **ENKLAVEN AB** [SE/SE]; Box 5006, S-402 21 Göteborg (SE).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **JOBSON, Edward** [SE/SE]; Jägarevägen 5, S-442 77 Romelanda (SE). **LARSSON, Mikael** [SE/SE]; Västerängsgatan 9, S-431 44 Mölndal (SE). **HEED, Björn** [SE/SE]; Utlandagatan 19, S-412 61 Göteborg (SE). **WITTE, Stefan** [SE/SE]; Fortgatan 3 A, S-426 76 Västra Frölunda (SE).

(74) Agents: **ANDERSSON, Per** et al.; Albihns Göteborg AB, P.O. Box 142, S-401 22 Göteborg (SE).

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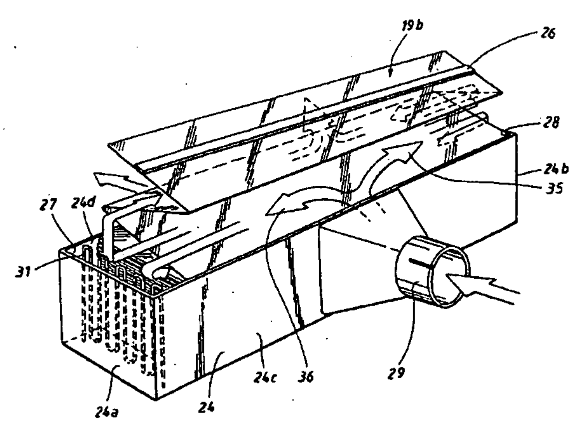
(54) Title: $NO_x$-REDUCING CATALYST WITH TEMPERATURE REGULATION OF EXHAUST GASES




(57) Abstract: The invention relates to a method for treatment of a gas-flow in connection with an $NO_x$ reducing catalyst (18), comprising guiding the gas-flow through an exhaust gas treatment unit (18) comprising several ducts (21) with exchange of heat between the ducts (21) and wherein the ducts (21) are connected to an inlet and an outlet, respectively, at the exhaust gas treatment unit (18) so that the gas-flow occurs during exchange of heat between incoming and outgoing flows, and reduction of $NO_x$ compounds in said gas-flow by means of said $NO_x$ reducing catalyst (18). The invention is characterized in that it comprises an adaption of the temperature of the exhaust gas treatment unit (18) to the prevailing operating condition of said $NO_x$ reducing catalyst (18). The invention also relates to a device for accomplishing said method. By means of the invention, an improved treatment of a gas-flow is provided, in particular in connection with exhaust gas purification in a combustion engine, by means of which the difficulty in combining a required exhaust gas temperature for $NO_x$ reduction with the demand for a suitable temperature for sulphur regeneration can be solved.

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TITLE

**$NO_x$-reducing catalyst with temperature regulation of of exhaust gases.**

TECHNICAL FIELD:

The present invention relates to a method for treatment of a gas-flow, according to the preamble of appended claim 1. The invention is particularly intended for use in the field of purification of exhaust gases in connection with a combustion engine which in particular is adapted for reduction of undesired nitric oxide compounds ($NO_x$ compounds) in the exhaust gases. The invention also relates to an arrangement for accomplishing such a treatment, according to the preamble of appended claim 10.

BACKGROUND OF THE INVENTION:

In the field of vehicles which are operated by combustion engines, there is a general demand for low emissions of harmful substances in the exhaust gases from the engine. Said substances are primarily constituted by pollutants in the form of nitric oxide compounds ($NO_x$), hydrocarbon compounds (HC), and carbon monoxide (CO). As regards today's petrol engines, the exhaust gases are normally purified by means of an exhaust catalyst which forms part of the exhaust system and through which the exhaust gases are guided. In a so-called three-way catalyst, which is previously known, the major part of the above-mentioned harmful compounds is eliminated by means of known catalytic reactions. In order to optimise the function of the catalyst so that it provides an optimal degree of purification for $NO_x$, HC, and CO, the engine is in most operating cases operated with a stoichiometric air/fuel mixture, i.e. a mixture where $\lambda=1$.

Furthermore, in the field of vehicles, there is a general demand for reducing the fuel consumption of the engine to the highest possible degree. To this end, during the last few years, new types of engines have been developed which are adapted to be able to be operated by increasingly lean fuel

mixtures, i.e. where $\lambda>1$. In a so-called DI engine (i.e. a direct-injected Otto cycle engine), the respective combustion chamber in the engine is constructed in such manner that the supplied fuel can be concentrated to a high degree at the respective ignition plug. This mode of operation is generally termed "stratified" operation and during continuous driving at a low or a medium-high torque and engine speed of the engine, it provides an operation with a very lean air/fuel mixture, more precisely up to approximately $\lambda=3$. In this manner, a substantial saving in the fuel consumption is obtained in this type of engine. The engine can also be operated in an additional, "homogeneous" mode of operation, with an essentially stoichiometric mixture ($\lambda=1$) or a comparatively rich mixture ($\lambda<1$). This later mode of operation normally prevails during driving situations with comparatively high torques and engine speeds of the engine.

During stratified operation, a lean exhaust gas mixture will flow through the three-way catalyst. This results in that the three-way catalyst cannot be utilized for reducing the $NO_x$ compounds in the exhaust gases (due to the fact that the three-way catalyst does not function well for purification of $NO_x$ compounds during conditions which are rich in oxygen). For this reason, a conventional three-way catalyst can be combined with a nitric oxide adsorbent (also called $NO_x$ adsorbent, or "$NO_x$ trap"), which is a per se known device for absorption of $NO_x$ compounds, e.g. in the exhaust gases from a combustion engine. In this manner, the $NO_x$ adsorbent can be utilized as a complement to a conventional three-way catalyst, either as a separate unit upstream of the three-way catalyst or as an integral part of the three-way catalyst, i.e. together with the catalytic material of the three-way catalyst. In the latter case, an integrated component in the form of a $NO_x$ adsorbing exhaust catalyst is formed.

The $NO_x$ adsorbent is constructed in such manner that it takes up (adsorbs) $NO_x$ compounds in the exhaust gases if the engine is operated with a lean

air/fuel mixture and discharges (desorbs) the $NO_x$ compounds if the engine is operated with a rich air/fuel mixture during a certain time period. Furthermore, the $NO_x$ adsorbent has the property of being able only to adsorb $NO_x$ compounds up to a certain limit, i.e. it is eventually "filled" and thus reaches a limit for the adsorption. In this situation, the $NO_x$ adsorbent must be regenerated, i.e. it must be influenced to desorb and thus to release the accumulated $NO_x$ compounds. If a conventional three-way catalyst in this case is provided in connection with a $NO_x$ adsorbent, or if alternatively a three-way catalyst is formed as an integral part of a $NO_x$ adsorbent, the desorbed $NO_x$ compounds can be eliminated by means of the three-way catalyst, provided that the latter has reached its ignition temperature. In principle, the conventional three-way catalyst can be arranged either before the $NO_x$ adsorbent, after the $NO_x$ adsorbent or as an integral part of the $NO_x$ adsorbent.

According to the prior art, a $NO_x$ adsorbent can be regenerated by means of the exhaust gas mixture which flows through the $NO_x$ adsorbent being made comparatively rich during a certain time period, approximately a few seconds. This can in turn be achieved by operating the engine with a comparatively rich air/fuel mixture during said time period. In practice, this is achieved by operating the engine during this time period in the above-mentioned homogeneous mode of operation, wherein the engine thus is operated by a comparatively rich air/fuel mixture. In this manner, the $NO_x$ adsorbent is "emptied" so that it subsequently can adsorb $NO_x$ compounds during a certain time period which lasts until a new regeneration becomes necessary.

According to prior art, a control unit is utilized which functions in accordance with a suitable strategy for, for example, switching the combustion engine between homogeneous and stratified operation depending on the degree of throttle application and the engine speed of the engine, and with regard to whether a $NO_x$ regeneration is necessary.

During purification of the exhaust gases from, for example, a DI engine, there is a demand for the capability of controlling the temperature of the $NO_x$ adsorbent in order to, among other things, achieve maximal reduction of $NO_x$ compounds in the exhaust gases. This is due to the fact that a $NO_x$ adsorbent only functions optimally within a certain temperature interval, which in turn depends on the prevailing operating condition. As an example, it can be mentioned that stratified mode of operation in a DI engine (i.e. operation with a lean air/fuel mixture) requires that the temperature of the exhaust gases which are guided through the $NO_x$ adsorbent lies within the interval of approximately 250-450° C in order for it to be able to operate with a satisfying function. A particularly efficient $NO_x$ reduction is obtained if the temperature lies within the interval of approximately 300-350° C. Furthermore, there is a general demand for the exhaust temperature not to exceed approximately 800° C, which is due to the fact that there is a risk of the $NO_x$ adsorbent being destroyed during temperatures which exceed this limit.

The demand for the capability of controlling the temperature generally prevails in connection with other types of engines as well, e.g. diesel engines, conventional port-injected Otto cycle engines, where a correct adjustment of the temperature to the function of the $NO_x$ adsorbent is desirable.

One particular phenomenon which arises in connection with a $NO_x$ adsorbent is that sulphur compounds (e.g. sulphur dioxide, $SO_2$), which are present in the exhaust gases which are guided through the $NO_x$ adsorbent, cause a coating on the active material of the $NO_x$ adsorbent. This coating in turn deactivates the $NO_x$ adsorbent's capacity to adsorb $NO_x$ compounds, which is due to the fact that sulphur compounds are adsorbed instead of $NO_x$ compounds. The sulphur compounds originate from the fuel of the engine, and may vary, among other things, depending on the prevailing fuel quality.

As a consequence of such a sulphur coating, the adsorption capacity of the $NO_x$ adsorbent will be gradually reduced in course of time.

In order to solve the problem regarding such a sulphur coating, the $NO_x$ adsorbent must be regenerated regularly as regards sulphur compounds as well, i.e. it must be "emptied" of sulphur compounds, whereby the sulphur coating on the $NO_x$ adsorbent is removed. In this case, unlike the case regarding the $NO_x$ regeneration, it is not sufficient to generate rich exhaust gases in order to achieve this sulphur regeneration. Instead, a sulphur regeneration can be accomplished (according to the prior art) by operating the engine during a certain time period so that it generates a rich exhaust gas mixture (i.e. $\lambda<1$) at the same time as a comparatively high exhaust gas temperature is generated, more precisely an exhaust gas temperature that is higher than approximately 650° C, preferably within the interval of 650-750° C. In this manner, sulphur compounds can be desorbed, i.e. discharged from the $NO_x$ adsorbent, so that the latter once again can be utilized with a fully satisfying adsorption of $NO_x$ compounds.

According to prior art, the sulphur regeneration is preferably made with a suitable time interval which is determined on the basis of the lost $NO_x$ storage capacity of the $NO_x$ adsorbent, which in turn can be estimated on the basis of the sulphur content of the fuel of the vehicle in question and the vehicle's fuel consumption.

Thus, there is a problem in connection with known engine systems, which is due to the difficulty in combining the required exhaust gas temperature during lean driving (approximately 250-450° C) with the demand for a suitable temperature for sulphur regeneration (approximately 650-750° C), wherein it at the same time must be controlled that the temperature does not exceed its higher limit value (approximately 800° C).

SUMMARY OF THE INVENTION:

The object of the present invention is to provide an improved treatment of a gas-flow, in particular during exhaust gas purification in connection with a combustion engine, by means of which the above-mentioned problem is solved in an effective manner. Said object is accomplished by means of a method, the characterizing features of which will be apparent from appended claim 1. Said object is also accomplished by means of a device, the characterizing features of which will be apparent from appended claim 10.

The invention constitutes a method for treatment of a gas-flow in connection with a $NO_x$ reducing catalyst, comprising guiding the gas-flow through an exhaust gas treatment unit comprising several ducts with exchange of heat between the ducts and wherein the ducts are connected to an inlet and an outlet, respectively, at the exhaust gas treatment unit so that the gas-flow occurs during exchange of heat between incoming and outgoing flows, and reduction of $NO_x$ compounds in said gas-flow by means of said $NO_x$ reducing catalyst. The invention is characterized in that it comprises an adaption of the temperature of the exhaust gas treatment unit to the prevailing operating condition of said $NO_x$ reducing catalyst.

By means of the invention, a considerable advantage is accomplished in the form of an efficient exchange of heat, which in turn is utilized in order to facilitate the adaption of the temperature of the exhaust gas treatment unit which in turn provides an optimal degree of reduction of $NO_x$ compounds. In particular, the invention allows a gas-flow to be treated at a certain temperature with a low consumption of heat. During heating of the gas-flow, a certain amount of heat is consumed (for a certain gas volume), which subsequently can be recycled in order to heat a new inflowing gas volume. This results in an effect as regards the exchange of heat which requires a considerably less consumption of power than traditional heating systems which for example are based on separate heating elements, e.g. of the electrical type. Similar advantages are also attained in connection with cooling of the gas-flow.

An additional advantage of the invention relates to the fact that exothermic reactions, e.g. in the form of oxidation of hydrocarbons in connection with the exchange of heat, results in a rise in temperature which is higher that what would be the case without an exchange of heat. Consequently, a control of the engine in question which results in that large contents of non-combusted hydrocarbons are generated in the exhaust gas, results in a considerable increase of temperature in the exhaust gas treatment unit. This in turn results in an enhanced degree of freedom when the object is to provide a suitable temperature in the exhaust gas treatment unit.

Thus, by means of the invention, the problem regarding an efficient adaption of the temperature within two separate levels, i.e. for lean operation and for regeneration after sulphur poisoning, respectively, is solved. The latter occurs in particular in connection with engines which are operated by fuel having a large content of sulphur and would otherwise constitute the most important objection regarding the use of $NO_x$-storing catalysts on many markets.

Another advantage regarding the invention is that it provides a larger geometrical freedom to form the above-mentioned exhaust gas treatment unit compared with conventional catalysts through which the exhaust gases are flowing.

In this connection, the term "mode of operation", refers to operation of a combustion engine of, for example, the DI engine type according to a predetermined progress in time for injection of fuel and ignition of an air/fuel mixture. As examples of modes of operation of a DI engine, stratified and homogeneous modes of operation can be mentioned.

Advantageous embodiments of the invention will be apparent from the appended dependent claims.

BRIEF DESCRIPTION OF THE DRAWINGS:

The invention will be further described in the following with reference to a preferred embodiment and to the annexed drawings, in which

Fig. 1 shows principally an arrangement in which the present invention can be utilized,

Fig. 2 shows a manner of constructing a particular exhaust gas treatment unit which is utilized according to the invention,

Fig. 3 shows said exhaust gas treatment unit, and

Fig. 4 shows a detail view of said exhaust gas treatment unit.

PREFERRED EMBODIMENTS:

Fig. 1 shows a schematic view of an arrangement according to the present invention. According to a preferred embodiment, the invention is arranged in connection with a combustion engine 1 which is constituted by a so-called DI engine, i.e. an engine of the direct-injected Otto cycle engine type, where the injection of fuel to the engine 1 is adapted for at least two modes of operation with different air and fuel supply to the engine 1 and varying time sequences for injection of fuel and for ignition of the air/fuel mixture.

In accordance with what will described in detail below, the engine 1 is preferably adapted to be able to be set in a "stratified" mode of operation, wherein the supplied fuel is concentrated in the respective combustion chamber of the engine so that the engine during certain predetermined operating cases can be operated by a very lean air/fuel mixture, approximately $\lambda=3$. The stratified mode of operation is based on the fact that fuel is injected into the engine 1 so that it is mixed partially (i.e. non-homogeneously) with air, wherein a small "cloud" of mixed fuel and air is formed. Around this partial mixture there is essentially clean air. In this manner, ignition of a very lean mixture, approximately $\lambda=3$, can be accomplished. Compared with the case where $\lambda=1$, three times as much air

is in this case supplied with the same amount of fuel. By means of such an engine, considerable fuel savings are provided compared with engines which are operated with a stoichiometric mixture, i.e. where $\lambda$=1. Furthermore, the engine 1 can preferably be set in a "homogeneous" mode of operation during certain operating cases at comparatively high torques and engine speeds of the engine 1, wherein a stoichiometric or a comparatively rich mixture is supplied to the engine 1. In this case, this mixture – in contrast to what is the case during the stratified mode of operation – is essentially uniformly distributed in the combustion chamber.

It shall be noted that the invention is not limited for utilization in connection with merely DI engines, but that it also can be utilized in other applications, e.g. in connection with diesel engines and conventional port-injected Otto cycle engines. Generally, the invention can also be utilized for treatment of other types of gas-flows than in motor vehicles where there is a demand for an adjustment of the exhaust gas temperature to the prevailing mode of operation.

In the following, an embodiment of the invention will be described, wherein the engine 1 is assumed to be operated either in a stratified or a homogeneous manner. However, the invention is not limited to merely these two modes of operation. For example, the engine 1 can be operated in a homogeneous, lean mode of operation, which is based on the homogeneous mode of operation that is described above (wherein $\lambda$=1), but where the air/fuel mixture is comparatively lean, approximately 1,2-1,3.

The engine 1 is in a conventional manner supplied with inflowing air via an air inlet 2. Furthermore, the engine 1 is provided with a number of cylinders 3 and a corresponding number of fuel injectors 4. The respective injector 4 is connected to a central control unit 5 via an electrical connection 6. Preferably, the control unit 5 is computer based and is adapted to control the

fuel supply to each injector 4 with fuel from a fuel tank (not shown) in a known manner so that an air/fuel mixture which is adapted in every given moment is fed to the engine 1. The engine 1 according to the embodiment is formed in accordance with the "multi-point" injection type, where the correct amount of fuel to the engine 1 can be supplied individually to the respective injector 4 in a known manner.

During operation of the engine 1, the control unit 5 is adapted in a general manner for controlling the air/fuel mixture to the engine 1 so that it in every given moment is adapted to the prevailing mode of operation. The control of the engine 1 takes place in an essentially known manner depending on various parameters which reflect the mode of operation of the engine 1 and the vehicle in question. For example, the control of the engine can take place depending on the prevailing degree of throttle application, the engine speed, the amount of injected air to the engine and the oxygen concentration in the exhaust gases. To this end, the engine 1 is provided with, for example, a position detector 7 for the vehicle's accelerator pedal (not shown), an engine speed detector 8 for detection of the engine speed of the engine 1 and an air flow meter 9 for detection of the amount of supplied air to the engine 1, all of which are connected to the control unit 5 via corresponding electrical connections 10, 11 and 12, respectively. Furthermore, the system comprises a gas throttle 13, which preferably is electrically controllable and, for this reason, is provided with a controllable shifting motor 14, by means of which the gas throttle 13 can be set in a certain desired position so that a suitable amount of air is fed into the engine 1 depending on the prevailing mode of operation. Thus, the shifting motor 14 is connected to the control unit 5 via an additional connection 15.

To sum up, the engine 1 according to the invention is adapted to be able to assume several different modes of operation, each of which is characterized by specific air/fuel mixtures, injection times and ignition times. In this case, the control unit 5 is adapted to change between the various modes of

operation depending on, for example, the driving situation, the load and the engine speed.

The engine 1 that is shown in the drawing is of a five-cylinder type. However, it shall be noted that the invention can be utilized in engines having various numbers of cylinders and various cylinder configurations. For example, the injectors 4 are constituted by the type in which the fuel is injected directly into the respective cylinder 3.

During operation of the engine 1, its exhaust gases are guided out from the cylinders 3 via a branch pipe 16 and further on to an exhaust pipe 17 which is connected to the branch pipe 16. In accordance with the invention, an exhaust gas treatment unit 18 is provided further downstream along the exhaust pipe 17, wherein the construction and function of said unit will be described in detail hereinafter with reference to Figs. 2, 3 and 4.

According to what in particular is apparent from Fig. 2, the exhaust gas treatment unit 18 comprises a band 19a of metal, which by means of a suitable method (e.g. pressing or rolling) has been formed with corrugations 20 which extend in a predetermined angle in relation to the longitudinal direction of the band 19a. The band 19a is repeatedly folded in a zigzag form so that it forms a band package 19b. In this manner, an arrangement is formed where the above-mentioned corrugations 20 run crosswise in relation to each other in adjacent layers in the band package 19b. Moreover, the corrugations 20 function as spacers, by means of which several ducts 21 are formed which are separated from each other (see in particular Fig. 4) and through which a gas-flow is intended to be guided, in the present case thus a flow of exhaust gases from the engine 1.

The flow pattern in the ducts 21 is formed in such manner that the flow in the duct is constantly mixed and has a sufficient contact with the walls of the ducts 21. Moreover, according to what is shown in Fig. 2, the corrugations

can, in order to facilitate the folding of the band, be interrupted at regular intervals in order to be replaced with folding directions 22, 23 which extend at right angles to the band 19a.

According to what will be described in detail hereinafter, the band 19a is preferably coated with a catalytic material. The technique for coating surfaces with thin coatings of catalytic material is previously known, e.g. in connection with manufacture of conventional car catalysts. Furthermore, the band 19a is enclosed in a heat insulated housing 24 (the insulation is not shown in the drawings). The shape of said housing 24 is essentially rectangular and it comprises two end walls 24a, 24b, two sidewalls 24c, 24d, a lower wall 24e, and an upper wall 24f. The band package is sealed against the two sides 25, 26 which are arranged in parallel with the flow direction of the gas-flow through the band package. The end sections of the band package are however not sealed, but terminate in two turnover chambers 27, 28, according to what is apparent from in particular Fig. 3.

Furthermore, the housing 24 comprises an inlet which is provided with a nozzle 29 for connection of inflowing gas and an outlet which is provided with an additional nozzle 30 for connection of outflowing gas. By means of the folding of the band, connection takes place in a simple manner from the side of the package to all ducts on one side of the band package 19b, which is due to the fact that the two nozzles 19, 30 connect to a respective side of the band. The inlet and outlet, respectively, of the housing 24 are preferably situated centrally on the respective sidewall 24c, 24d. This corresponds to the fact that the inlet and the outlet, respectively, are positioned at essentially the same distance from the respective end wall, 24a, 24b. By means of this division of the gas-flow in two flows with only half the speed, the pressure drop decreases considerably.

According to what is apparent from Figs. 2 and 3, a particular heating element is 31 provided in each of the turnover chambers 27, 28. According to

the embodiment, the heating element 31 is constructed of electrical heating conductors which are adapted for generation of heat in the event of connection to a separate (not shown) voltage source. However, other types of heating elements can be utilized in connection with the invention, e.g. burners which are operated by gas or oil. According to an additional alternative, a heating function can be provided by means of a supply (not shown) of hot air (or some other suitable gas) from an external source.

However, the invention is not limited for utilization together with a separate heating element 31. Consequently, in some applications, the heating element 31 which is shown in the drawings can be excluded.

According to the embodiment, the band package 19b is formed in such manner that it is coated with a catalytic material which provides a function which corresponds to a three-way catalyst, i.e. which is utilized for catalytic elimination of undesired compounds in the form of nitric oxides, carbon monoxide and hydrocarbon compounds in the exhaust gases from the engine 1. Moreover, the band package 19b is also preferably provided with a $NO_x$ reducing coating, according to the embodiment in the form of a coating which provides a function of a nitric oxide adsorbent, $NO_x$ adsorbent. According to what has been described initially, a $NO_x$ adsorbent can in a known manner be utilized for reduction of $NO_x$ compounds in the exhaust gases of the engine 1.

Consequently, the exhaust gas treatment unit 18 constitutes an integrated component which comprises $NO_x$ reducing material as well as material which provides the function of a conventional three-way catalyst. By means of the special design of the band package 19b, the invention provides excellent opportunities for controlling the temperature of the flowing gas-flow. This will be described in detail below.

The invention is not limited to said design as an integrated unit which simultaneously functions as three-way catalyst and $NO_x$ adsorbent, but may also be based on the fact that the exhaust gas treatment unit exclusively comprises $NO_x$ adsorbing material and is connected to a separate unit in the form of a three-way catalyst. Inversely, the exhaust gas treatment unit can comprise catalytic material which provides the function of a three-way catalyst, whereas a separate unit in the form of a $NO_x$ adsorbent in this case is arranged upstream of the exhaust gas treatment unit. According to an additional alternative, the exhaust gas treatment unit can be formed without either a $NO_x$ adsorbent or a three-way catalyst, wherein both these functions in this case are provided by means of separate units in connection with the exhaust gas treatment unit.

Whichever specific design is selected in the present application depends, for example, on how the space in the present vehicle can be utilized. Other factors which determine the selection of design are demands for an acceptable heating effect, pressure drop and loss of heat and factors regarding the production and the cost.

Irrespective of which specific design that is selected in a specific case, the exhaust gas purification unit 18 is indicated in the drawings as an integrated unit which functions as a $NO_x$ adsorbent as well as a three-way catalyst.

Furthermore, according to the embodiment, the engine 1 is connected to a pre-catalyst 32 of the three-way type and with a comparatively low oxygen storage capacity, which is provided upstream of the exhaust gas treatment unit 18 and preferably comparatively close to the exhaust manifold 16. The pre-catalyst 32 is particularly adapted for rapid heating during cold starts of the engine 1, i.e. so that its catalytic coating becomes active rapidly. This provides a considerable elimination of HC, CO, and $NO_x$ compounds in the exhaust gases, particularly during low gas flows. Due to the fact that the flowing exhaust gases can be heated rapidly by means of the pre-catalyst 32,

a comparatively rapid heating is also provided for the subsequent exhaust gas treatment unit 18, i.e. a comparatively short time that passes until the exhaust gas treatment unit 18 has been heated to a temperature at which it is capable of reducing a predetermined part of the harmful substances in the exhaust gases. This results in an efficient exhaust purification for the engine 1, particularly during cold starts.

One particular object of the pre-catalyst 32 in connection with the present DI engine 1 relates to the fact that engines of such kind generally discharges comparatively large amounts of non-combusted residues in the exhaust gases. In this case, said residues are allowed to be combusted in the pre-catalyst 32, by means of which a too large exothermic reaction in the $NO_x$ adsorbing material of the exhaust gas treatment unit 18 can be avoided. Moreover, the pre-catalyst 32 can have a certain positive effect as regards sulphur poisoning of the $NO_x$ adsorption.

Thus, the exhaust gases from the engine 1 flow through the exhaust pipe 17, through the pre-catalyst 32 and the exhaust gas treatment unit 18 and then further out into the atmosphere. During homogeneous operation of the engine 1, i.e. during essentially stoichiometric driving conditions (i.e. $\lambda=1$), the exhaust gas treatment unit 18 functions as a conventional three-way catalyst, i.e. for elimination of hydrocarbons (HC), carbon monoxide (CO) and nitric oxide compounds ($NO_x$). During lean modes of operation (i.e. $\lambda>1$) within a certain temperature window, more precisely approximately 250-450° C (according to what has been described initially), the major part of the $NO_x$ compounds which are emitted from the engine 1 is adsorbed by means of the $NO_x$ adsorbing material in the exhaust gas treatment unit 18.

Furthermore, the arrangement according to Fig. 1 comprises a sensor 33 for detection of the oxygen concentration in the exhaust gases. Preferably, the sensor 33 is of the linear lambda probe type (but may alternatively be

constituted by a binary probe or alternatively by some other sensor type, such as a $NO_x$ sensor or a HC sensor) and is connected to the control unit 5 via an electrical connection 34. Preferably, the sensor 33 is provided in the exhaust pipe 17, upstream of the pre-catalyst 32. However, other locations of the sensor 33 are possible, for example between the pre-catalyst 32 and the exhaust gas treatment unit 18 or inside the exhaust gas treatment unit 18. In a manner which is per se previously known, the sensor 33 is utilized for generating a signal which corresponds to the oxygen concentration in the exhaust gases. Said signal is fed to the control unit 5 via the connection 34 and is utilized for control of the air/fuel mixture to the engine 1.

The function of the invention will now be described in detail. During a comparatively low torque and low engine speeds, the engine 1 is adapted to be operated in a stratified operation, with a very lean air/fuel mixture. During a comparatively high torque and high engine speeds, the engine 1 is furthermore adapted to be operated in a homogeneous mode of operation, i.e. with a stoichiometric or essentially stoichiometric mixture. According to what has been mentioned above, the invention is however not limited to merely these two modes of operation. The choice of mode of operation takes place in accordance with tables which have been fixed in advance and which are stored in a memory unit in the control unit 5. On the basis of the prevailing engine speed of the engine 1, which is determined by means of the engine speed indicator 8, and the required torque for the engine 1, which can be detected by means of the level indicator 7 for the position of the accelerator pedal, the control unit 5 can determine whether the engine 1 shall be set in, for example, the stratified or the homogeneous mode of operation. For adjustment of the required mode of operation, a value of, for example, the prevailing inflowing amount of air into the engine may alternatively be utilized.

The switch between stratified and homogeneous operation can also occur in a compulsory manner as a consequence of a demand for regeneration of the

exhaust gas treatment unit 18. This can be made in the following manner. When the engine 1 is operated in a stratified manner, i.e. with a lean air/fuel mixture, the exhaust gas mixture which is guided through the exhaust pipe 17 and reaches the exhaust gas treatment unit 18 is also lean. According to known principles, the major part of the $NO_x$ compounds which are present in the exhaust gas mixture will in this case be adsorbed by the exhaust gas treatment unit 18. After driving with a lean exhaust gas mixture for a certain amount of time, normally approximately 1-2 minutes, the exhaust gas treatment unit 18 will be "full", which means that it is unable to absorb $NO_x$ compounds from the exhaust gas mixture to the same extent as before. At this stage, the exhaust gas treatment unit 18 must be regenerated. According to what has been described above, the demand for regeneration can be determined by means of the control unit 5, which in this case sets the engine 1 in the homogeneous mode of operation. This makes it possible to make the exhaust gas mixture through the exhaust gas treatment unit 18 comparatively rich during a certain time period, e.g. during a few seconds. In this manner, $NO_x$ compounds which previously have been adsorbed are desorbed, so that the exhaust gas treatment unit 18 once again is allowed to adsorb $NO_x$ compounds during a certain time period which lasts until it a new regeneration becomes necessary. When the $NO_x$ compounds have been desorbed from the exhaust gas treatment unit 18, they will also be reduced by means of the three-way catalyst which forms an integrated part of the exhaust gas treatment unit 18.

The times at which it is suitable to make the regeneration can be calculated by means of the control unit 5, and are determined depending on, among other things, the exhaust gas treatment unit 18 and its storage capacity for $NO_x$ compounds and its rate of adsorption. Said storage capacity of the exhaust gas treatment unit 18 is also affected by possible ageing and deactivation depending on sulphur compounds. When an excessive amount of sulphur has accumulated in the exhaust gas treatment unit 18, sulphur regeneration must be carried out. According to what has been mentioned

initially, this can be made according to prior art by operating the engine during a certain time period in such manner that it generates a rich exhaust gas mixture (i.e. $\lambda<1$) at the same time as a comparatively great generation of heat in the exhaust gas treatment unit 18 is provided, more precisely a temperature in the exhaust gas treatment unit 18 which is approximately 650-750° C. When sulphur compounds have been desorbed, the exhaust gas treatment unit 18 once again can be utilized for adsorption of $NO_x$ compounds.

During operation of the engine 1, exhaust gases are supplied through the exhaust gas treatment unit 18. In this case, the exhaust gases are guided via the inlet 29 (cf. Figs. 2 and 3) and are divided into two partial flows 35, 36 (cf. Fig. 3). Said flows 35, 36, are guided through the ducts on one side of the band package 19b and in the direction of the respective turnover chamber 27, 28. Initially, the supplied exhaust gases will be comparatively cold, but are gradually heated towards the reaction temperature at which the catalytic reactions and the $NO_x$ adsorption, respectively, in the exhaust gas treatment unit 18 are initiated. At the same time as hot exhaust gases are guided towards the outlet 30 of the exhaust gas treatment unit 18, additional exhaust gases enter via its inlet 29. In this case, heat will be transmitted from the outgoing gas-flow to the incoming gas-flow. By means of an effective exchange of heat between the outgoing and the incoming gas-flows, the local temperatures of said flows can be influenced to be close to each other. For this reason, only a small additional supply of heat in the turnover chambers 27, 28 is required in order to, for example, increase the temperature of the gas-flow. According to what has been mentioned above, no activation of separate heating elements (cf. the heating element 31) is normally required, particularly not after the chemical reaction in the exhaust gas treatment unit 18 has been initiated.

At the same time as the gas-flow is heat-treated to the correct temperature in the exhaust gas treatment unit 18, it is guided over the surfaces which constitute the three-way catalyst and the $NO_x$ adsorbent, respectively. The principles for this guiding of the gas-flow are per se previously known from the Swedish patent application nr. SE 9402630-9 and are therefore not described in detail here.

According to what has been described initially, there is a general demand for an accurate temperature control of the exhaust gases, in particular as a consequence of the conflicting demands which are the result of the demand for, on the one hand, a high temperature (at least approximately 650° C) during sulphur regeneration and, on the other hand, a comparatively low temperature (approximately 250-450° C) during $NO_x$ adsorption in connection with lean operation. Moreover, the temperature must at all events be below approximately 800° C, since the function of the $NO_x$ adsorbent otherwise run the risk of ceasing.

In order to meet this demand, a basic principle of the invention is that the temperature of the prevailing gas-flow is adjusted to the prevailing operating condition of the engine 1, which results in that the temperature of the exhaust gas treatment unit 18 will end up within the above-mentioned interval during lean operation and at a sufficiently high value during sulphur regeneration. Furthermore, the invention is adapted for limitation of the temperature to a lower value than a limit value which is known beforehand and which corresponds to thermal deactivation of the $NO_x$ adsorbent.

In order to achieve, for example, an increase of the temperature of the exhaust gas treatment unit 18, exothermic reactions, which occur as a consequence of the energy content in the exhaust gases, are utilized. Furthermore, an increase of the temperature can be obtained as a result of a change of the energy content in the exhaust gases by means of a suitable

engine control, wherein the control unit 5 is utilized. This can in turn be achieved by means of, for example, a modification of the time for the injection and the ignition or by means of additional injection during the exhaust stroke. Furthermore, an increase of the temperature of the exhaust gases can be achieved by means of periodic control between rich and lean conditions of the exhaust gases. The periods between the rich pulses can be varied, and so can their length. Preferably, period times of approximately one second are utilized. In this manner, it is possible to control the extent of the exothermic reaction as well as the position in the catalytic material of the exhaust gas treatment unit 18 where it shall occur. An additional manner of achieving an increase of the temperature is by blowing in air from an external source (not shown) into the exhaust gas treatment unit 18 during rich operation of the engine. An additional manner of providing an increase of the temperature is by means of a control of each individual cylinder, wherein the exhaust gases from one or some of the cylinders are operated in a rich manner whereas the rest of the cylinders are operated in a lean manner. If the exhaust gases are mixed before they reach the three-way catalyst, a strong exothermic reaction occurs in this catalyst, which results in a generation of heat. In the latter case, it is particularly suitable to keep the exhaust gases from the respective cylinder separated in such manner that they are mixed only after they have reached the exhaust gas treatment unit 18. In this manner, the exothermic reaction can take place on the $NO_x$ adsorbent.

According to what has been mentioned above, an additional possible manner of increasing the temperature of the gas-flow is by means of heat which is supplied externally. For example, this can be supplied through the above-mentioned heating element 31 or alternatively through a burner or an external fuel injection.

In those cases where the invention is utilized in diesel engines, it is not suitable to operate the engine in a rich manner in some types of diesel

engines. In such a case, an increase of the temperature can instead be achieved by means of injection of fuel directly into the exhaust gases after the engine or in connection with the exhaust stroke in the engine. In such a case, fuel (or some other reduction means) can be portioned out both before the exhaust gas treatment unit 18, e.g. in one of the turnover chambers 27, 28, or directly into the exhaust gas treatment unit 18 between its inlet and the turnover chambers 27, 28 (or between the turnover chambers and their outlets).

If required, the temperature of the exhaust gas treatment unit 18 can also be lowered in several manners, e.g. by means of external cooling. More precisely, this could be implemented by means of supply of, for example, water or air, which in this case is supplied through the exhaust gas treatment unit 18. This is not shown in the drawings. An additional manner is to utilize cooling flanges (not shown) in the exhaust gas treatment unit 18. In this case, said cooling flanges can be controlled by means of bimetals, which results in a system which can be utilized for temperature control without the need to utilize the control unit 5.

An additional possibility of lowering the temperature in the exhaust gas treatment unit 18 is to supply cold air, for example from an air pump (not shown), into the turnover chambers 24. Due to the effect of the exchange of heat which is obtained according to the invention, even small amounts of supplied air results in a considerable drop in temperature of the gas-flow through the exhaust gas treatment unit 18.

The supplied cold air can be non-compressed or compressed. According to one solution, the supplied air can be constituted by compressed air which is taken from the induction pipe of the engine, preferably after a compressor (not shown) forming part of a turbo-aggregate (not shown). Alternatively, the cold air can be constituted by exhaust gases which are guided out from the

exhaust manifold of the engine (before the turbo-aggregate) and which are cooled down (e.g. by means of a suitable form of after-treatment).

The main principle for external cooling is to carry off heat from the turnover chambers 27, 28 essentially without mass exchange. During air admission, the heat that is present will be "diluted" and the temperature drops by means of a supply of cold gas into the flow. In both cases, the principle of exchange of heat provides an upscaling and results in a considerable enhanced effect as regards the temperature.

By means of an arrangement of the above-mentioned kind, an effective control of the temperature of the gas-flow is obtained, so that said gas-flow can be controlled and adjusted to a value which is optimally adapted to the prevailing operating condition. This is particularly achieved by means of the fact that the design of the exhaust gas treatment unit 18 provides a satisfying heat transmission and a catalytic effect by means of a satisfying contact between the flowing gas and the walls in the exhaust gas treatment unit 18.

The invention provides an adaption of the temperature in the exhaust gas treatment unit 18 to the prevailing operating condition in its $NO_x$ adsorbing material. In order to facilitate this adaption, the invention can comprise a temperature sensor (not shown) which is provided in connection with the exhaust gas treatment unit 18. In this case, such a temperature sensor can be connected to the control unit 5 via an electrical connection and deliver a measurement value which corresponds to the prevailing temperature of the exhaust gas treatment unit 18. In this case, said measurement value can be utilized during the control of an increase and a lowering, respectively, of the temperature of the exhaust gas treatment unit 18, according to the methods which in turn have been explained above. In this manner, an accurate control of the temperature of the exhaust gas-flow is provided.

However, it shall be noted that the invention is not limited to merely the type of system which comprises such a separate temperature sensor, but the invention can also be realized by providing the control unit 5 with a program with a calculation model which predicts the temperature of the exhaust gas treatment unit 18 during various operating conditions with a satisfying accuracy.

The invention is not limited to the embodiment which is described above and shown in the drawings, but may be varied within the scope of the appended claims. For example, the band 19a can be manufactured by a thin metal plate or foil, e.g. by stainless steel, which has been coated with the above-mentioned catalytic material. Alternatively, the band 19a can consist of a ceramic material which has been impregnated or coated with the catalytic material. Furthermore, the material can alternatively be manufactured in the form of thin sheets or similar elements, which in this case are arranged in a package and subsequently are joined together along the edges so that the above-mentioned band package 19b is formed.

If the exhaust gas treatment unit 18 comprises material which provides the function of a three-way catalyst and a $NO_x$ adsorbent, respectively, these materials can be provided in different ways. For example, said materials can be provided on various areas along the exhaust gas treatment unit 18. For example, the inlet part of the exhaust gas treatment unit 18 can function as a three-way catalyst whereas the inner parts of the exhaust gas treatment unit 18 functions as a $NO_x$ adsorbent. In this case, by means of a suitable design, the above-mentioned pre-catalyst 32 can also be eliminated.

Furthermore, the part of the band 19a which is situated closest to the inlet can be formed in such manner that it functions as a three-way catalyst with a particularly low oxygen storage capacity. This is advantageous for reducing the fuel consumption, which is due to the fact that less fuel is spent on the way to the $NO_x$ adsorbing material.

The inlet and the outlet, respectively, of the exhaust gas treatment unit 18 can be positioned according to what has been explained above, i.e. essentially centrally on the respective side wall 24c, 24d. Alternatively, it is possible to position the inlet and the outlet displaced towards either direction along the respective sidewall.

The invention is not limited for utilization in connection with merely DI engines, but it can also be utilised in other applications, e.g. in connection with diesel engines or conventional port-injected Otto cycle engines. Generally, the invention is not limited for utilization in connection with motor vehicles, but it may be applied in other applications where there is a demand for adjusting the temperature of a gas-flow.

Moreover, the invention can be utilized during ammonia based $NO_x$ reduction (so called SCR technology) or alternatively hydrocarbon based $NO_x$ reduction, where there also is a demand for obtaining a correct operating temperature during $NO_x$ reduction. As an example, injection of urea (in accordance with SCR technology) can be mentioned, wherein the $NO_x$ reduction only functions within a certain temperature interval, more precisely approximately 300-500° C.

According to one possible embodiment of the invention, it can be formed so that $NO_x$ compounds which are stored in the $NO_x$ adsorbent are allowed to be discharged without being reduced in the $NO_x$ trap. In other words, the invention is not limited to the fact that reduction of $NO_x$ compounds takes part in the $NO_x$ adsorbent. For example, a thermal desorption in the $NO_x$ adsorbent can be utilized.

CLAIMS

1. Method for treatment of a gas-flow in connection with a $NO_x$ reducing catalyst (18), comprising

guiding the gas-flow through an exhaust gas treatment unit (18) comprising several ducts (21) with exchange of heat between the ducts (21) and wherein the ducts (21) are connected to an inlet and an outlet, respectively, at the exhaust gas treatment unit (18) so that the gas-flow occurs during exchange of heat between incoming and outgoing flows, and

reduction of $NO_x$ compounds in said gas-flow by means of said $NO_x$ reducing catalyst (18),

characterized in that it comprises an adaption of the temperature of the exhaust gas treatment unit (18) to the prevailing operating condition of said $NO_x$ reducing catalyst (18).

2. Method according to claim 1, wherein said $NO_x$ reducing exhaust catalyst (18) and said exhaust gas treatment unit (18) are provided in connection with a combustion engine (1) in a vehicle,

characterized in that it comprises an adaption of said temperature of the exhaust gas treatment unit (18) depending on the prevailing operating condition of the engine (1) and the exhaust catalyst (18).

3. Method according to claim 2,

characterized in that said temperature is adapted to whether an essentially lean exhaust gas mixture flows through the exhaust catalyst (18) or whether a sulphur regeneration of the exhaust catalyst (18) is carried out.

4. Method according to any of the preceding claims,

characterized in that it comprises increasing alternatively lowering of the temperature of the gas-flow which flows through the exhaust gas treatment unit (18), for said adaption.

5. Method according to claim 4,
characterized in that said increase of the temperature is provided by means of at least one of the following measures:

i) controlling the injection time and the ignition sequence of said engine (1) so that an increased exhaust gas temperature is obtained,

ii) controlling said engine (1) wherein an additional injection of fuel is made during the exhaust stroke of the engine,

iii) periodically controlling said engine (1) between rich and lean operation,

iv) admitting air from an external source and into the exhaust gas treatment unit (18) during rich operation of the engine (1),

v) controlling each cylinder so that the exhaust gases from one or some of the cylinders of the engine (1) are operated in a rich manner whereas the rest of the cylinders are operated in a lean or stoichiometric manner,

vi) supplying heat through a heating element (31) which is provided in the exhaust gas treatment unit (18),

vii) injecting fuel in the exhaust gases after the engine (1).

6. Method according to claim 4,
characterized in that said lowering of the temperature is obtained by means of at least one of the following measures:

i) supplying a liquid or air from an external source and through the exhaust gas treatment unit (18),

ii) guiding the gas-flow past especially arranged cooling flanges in the exhaust gas treatment unit (18),

iii) supplying air from the inlet duct of the engine (1),

iv) supplying cooled exhaust gases from the engine's (1) exhaust manifold (16).

7. Method according to any of the preceding claims,
characterized in that said reduction of $NO_x$ compounds in said gas-flow is provided by means of at least one of the following measures:

i) operating the engine (1) with an essentially rich exhaust gas mixture,

ii) injecting fuel or some other reducing agent into the exhaust gases,

iii) injecting ammonia or urea, or generating ammonia which is supplied to the exhaust gases.

8. Method according to any of the preceding claims,
c h a r a c t e r i z e d i n that it comprises determining the temperature of said exhaust gas treatment unit (18) by means of predetermined calculation models which define a relationship between said temperature and the prevailing operating condition of the engine (1).

9. Method according to any of claims 1-7,
c h a r a c t e r i z e d i n that it comprises determining the temperature of said exhaust gas treatment unit (18) by means of a separate temperature sensor which is provided in connection with the exhaust gas treatment unit (18).

10. Device for treatment of a gas-flow comprising an exhaust gas treatment unit (18) with several ducts (21) providing exchange of heat between the ducts (21) and wherein the ducts (21) are connected to an inlet and an outlet, respectively, of the exhaust gas treatment unit (18) so that the gas-flow occurs during exchange of heat between incoming and outgoing flows, and a $NO_x$ reducing catalyst (18) for reduction of $NO_x$ compounds in said gas-flow,
c h a r a c t e r i z e d i n that it comprises a control unit (5) which is adapted for controlling the temperature of the exhaust gas treatment unit (18) for said adaption to the prevailing operating condition of said $NO_x$ reducing catalyst (18).

11. Device according to claim 10,
c h a r a c t e r i z e d i n that said exhaust gas treatment unit (18) comprises a band (19a) which is folded into a package (19b), by means of which said ducts (21) are formed.

12. Device according to claim 10 or 11,
c h a r a c t e r i z e d i n that said $NO_x$ reducing exhaust catalyst (18) and said exhaust gas treatment unit (18) are integrated into the same unit (18).

13. Device according to any of claims 10-12,
c h a r a c t e r i z e d i n that it comprises a separate temperature sensor which is connected to the control unit and which is adapted for determining the temperature of the exhaust gas treatment unit (18).

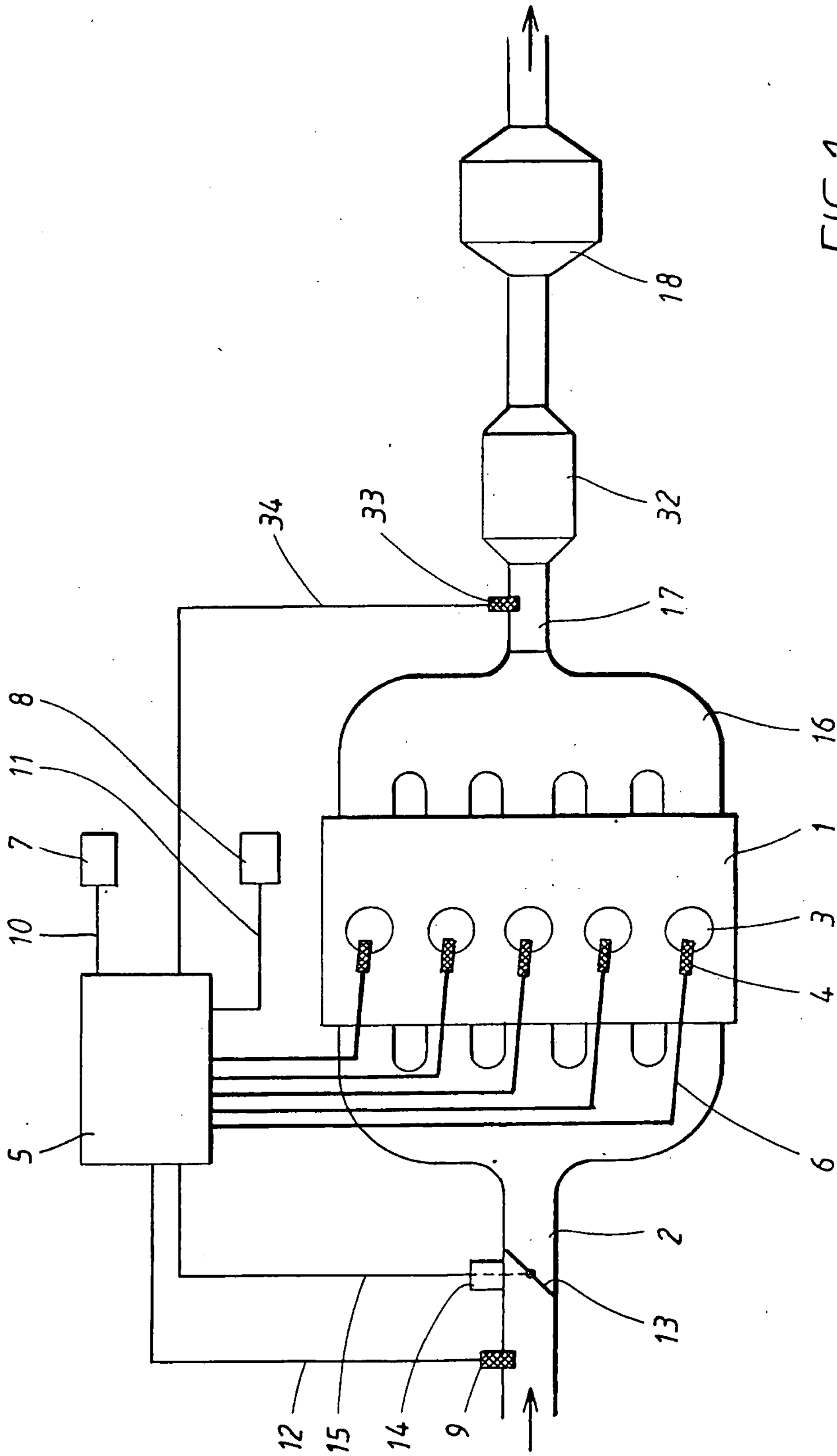


FIG.1

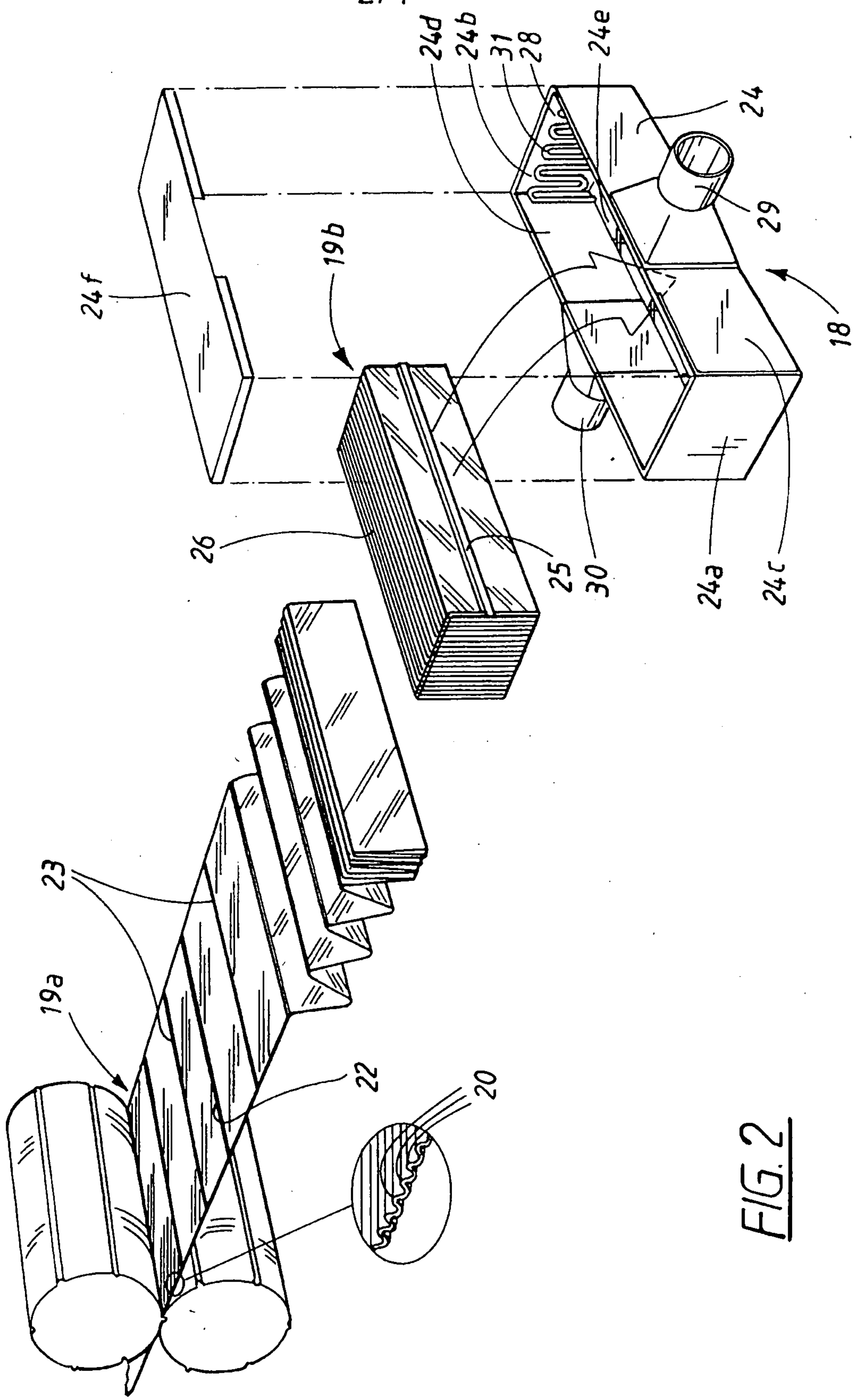


FIG. 2

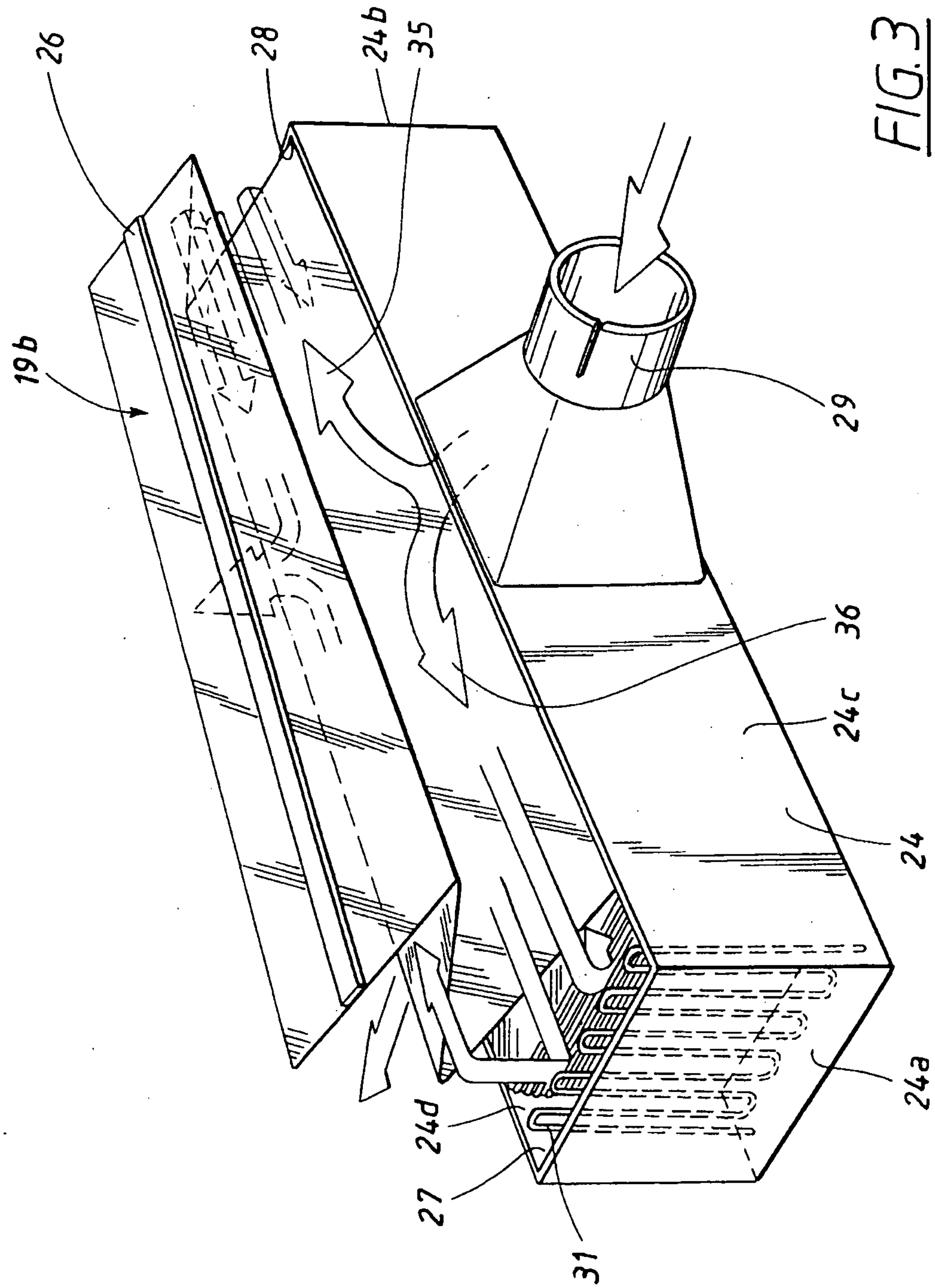


FIG.3

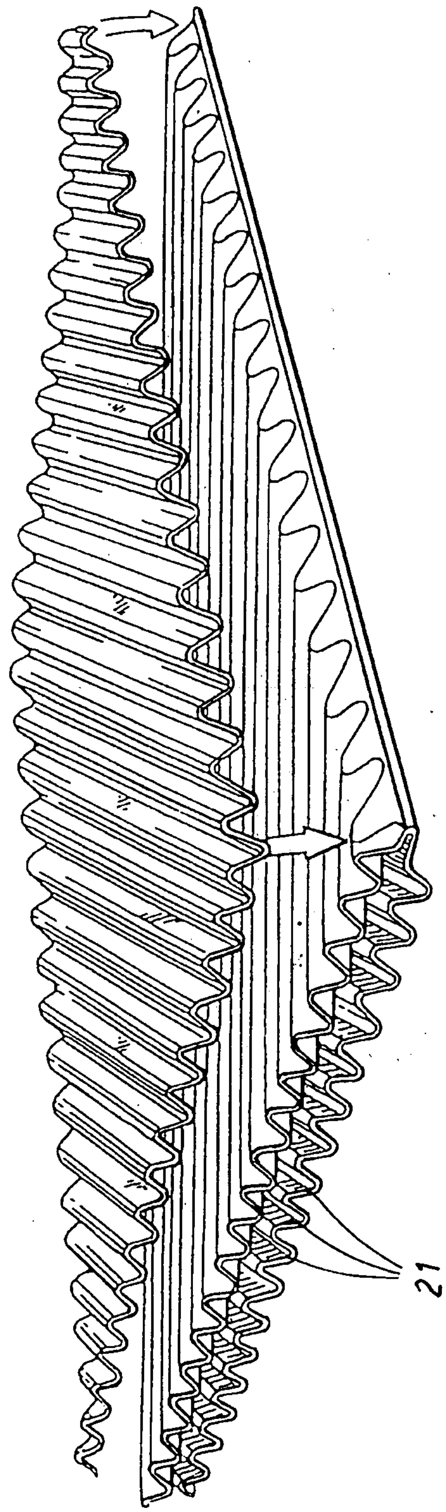


FIG. 4

# INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 00/02672

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: F01N 3/28, F23G 7/06
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: F01N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

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* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
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"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 7 May 2001 | 09-05-2001 |

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|---|---|
| Swedish Patent Office<br>Box 5055, S-102 42 STOCKHOLM<br>Facsimile No. +46 8 666 02 86 | Johan Westerbergh/ELY<br>Telephone No. +46 8 782 25 00 |

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